Characterization of Nitrogen and Phosphorus in Groundwater Discharging to Lake Spokane

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Spokane River Forum – March 2016

Coeur d'Alene, ID

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U.S. Geological Survey

Introduction

- General Problem: Excess nutrient (phosphorous) loading to Lake Spokane causing increased growth of aquatic plants and algae and low dissolved oxygen (DO) conditions in parts of the lake
  - Ecology listed the lake on the 303(d) list for low DO and developed a total maximum daily load (TMDL) for phosphorus in 1992
  - Revised in 2010 after continued algal blooms and water quality concerns
- Progress has been made to reduce point sources of phosphorus to the lake from upstream
- Now, focus is more on non-point sources of N and P to the lake (groundwater, onsite septic systems)

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Introduction

- Question: Are significant levels of nutrients from groundwater and on-site septic systems (OSS) reaching Lake Spokane?
- Approach to this question is taking place in two phases.
  - Phase 1 – general survey of aquatic plants for analysis of ^{15}N, a stable isotope of nitrogen, indicative of wastewater influence; preliminary sampling of shallow groundwater chemistry
  - Phase 2 – Expand the shallow groundwater chemistry sampling and add-on measurements of groundwater seepage in order to estimate fluxes entering the lake.
- Timeline – phase 1 is completed and report published; phase 2 just beginning, expected completion in late 2018

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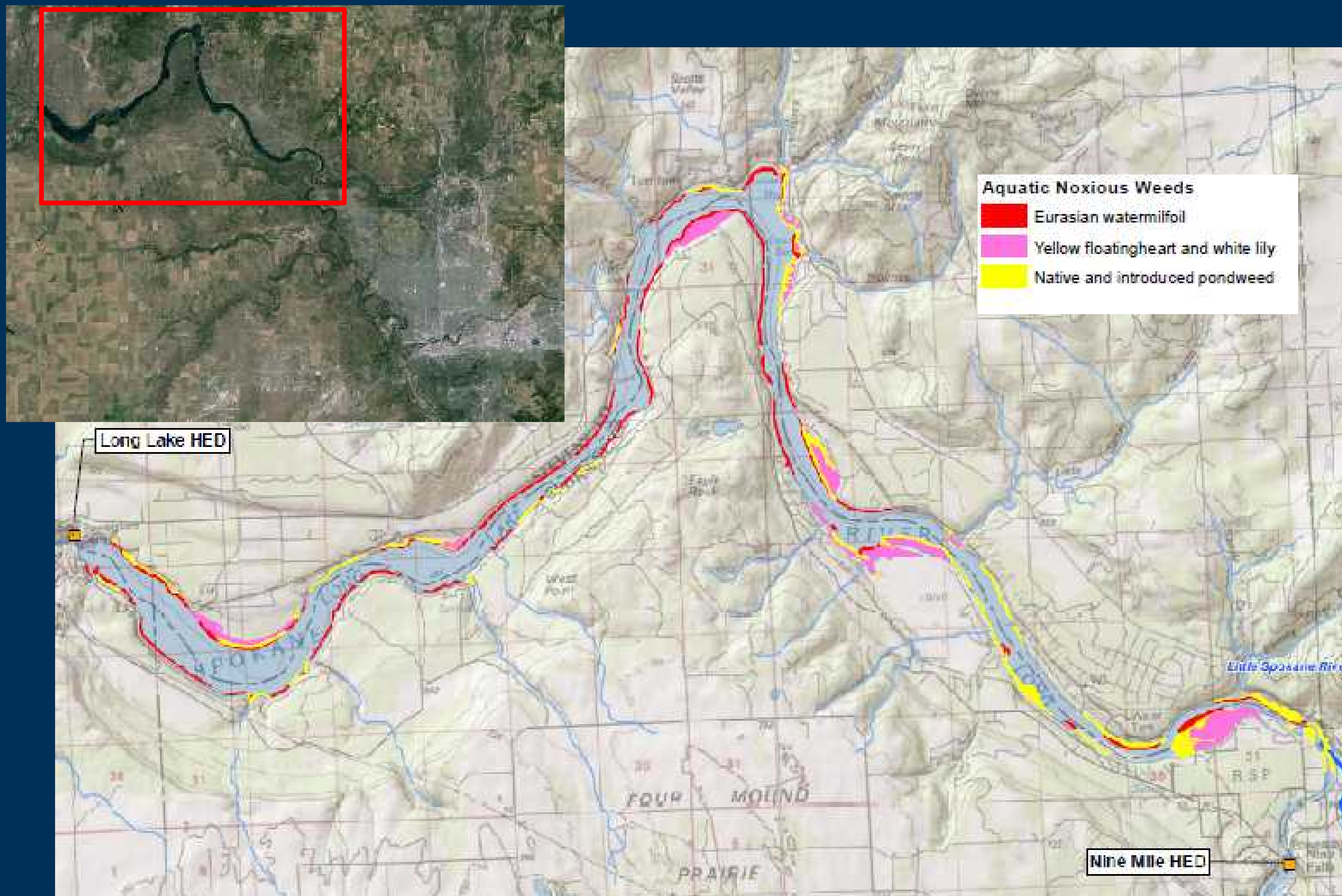
Study area: Lake Spokane



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From: Avista, 2012 FERC

Onsite Septic Systems (OSS) along Lake Spokane

- ~ 1,600- 1,700 OSS along Lake Spokane shoreline
- Nutrients including nitrogen and phosphorus are released through OSS drain fields and infiltrate to GW
- Some nitrate is reduced in drain fields, but it is highly mobile in the subsurface
- Phosphorus; some absorbs to sediment and some can move with groundwater into the lake

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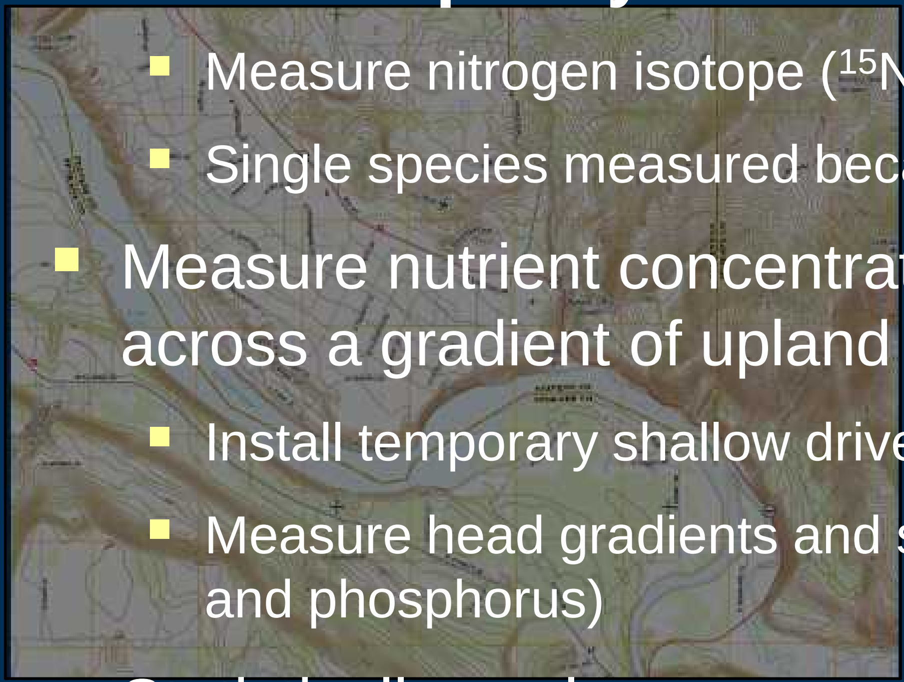
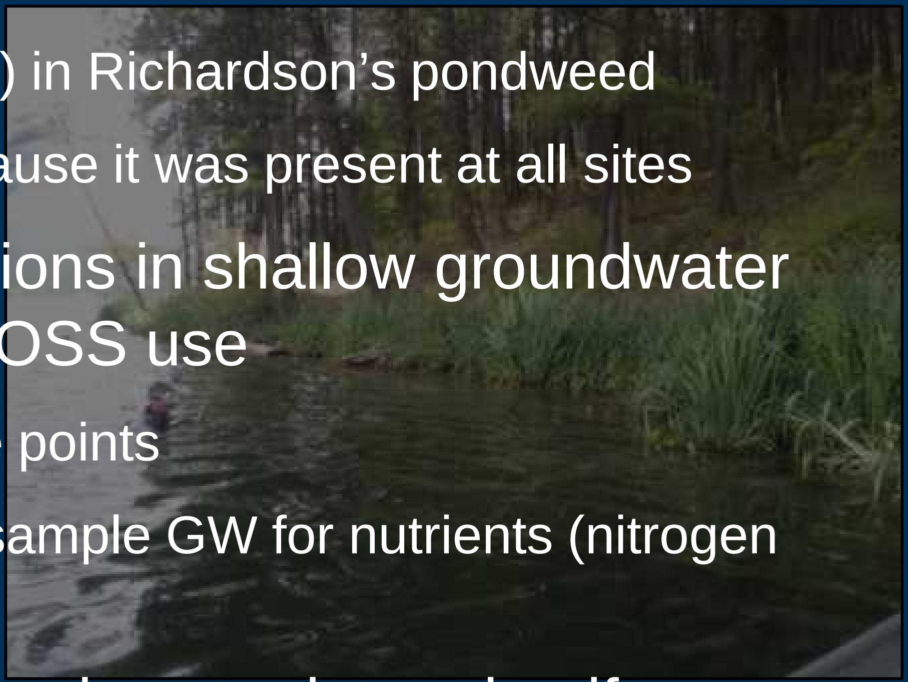
Phase 1 Approach

- **Try to identify areas where groundwater inflow may contain septic-system effluent**





  - Measure nitrogen isotope (^{15}N) in Richardson's pondweed
  - Single species measured because it was present at all sites
- Measure nutrient concentrations in shallow groundwater across a gradient of upland OSS use
  - Install temporary shallow drive points
  - Measure head gradients and sample GW for nutrients (nitrogen and phosphorus)
- Statistically analyze concentrations to determine if a difference exists between nutrient concentrations downgradient of developed and undeveloped land.

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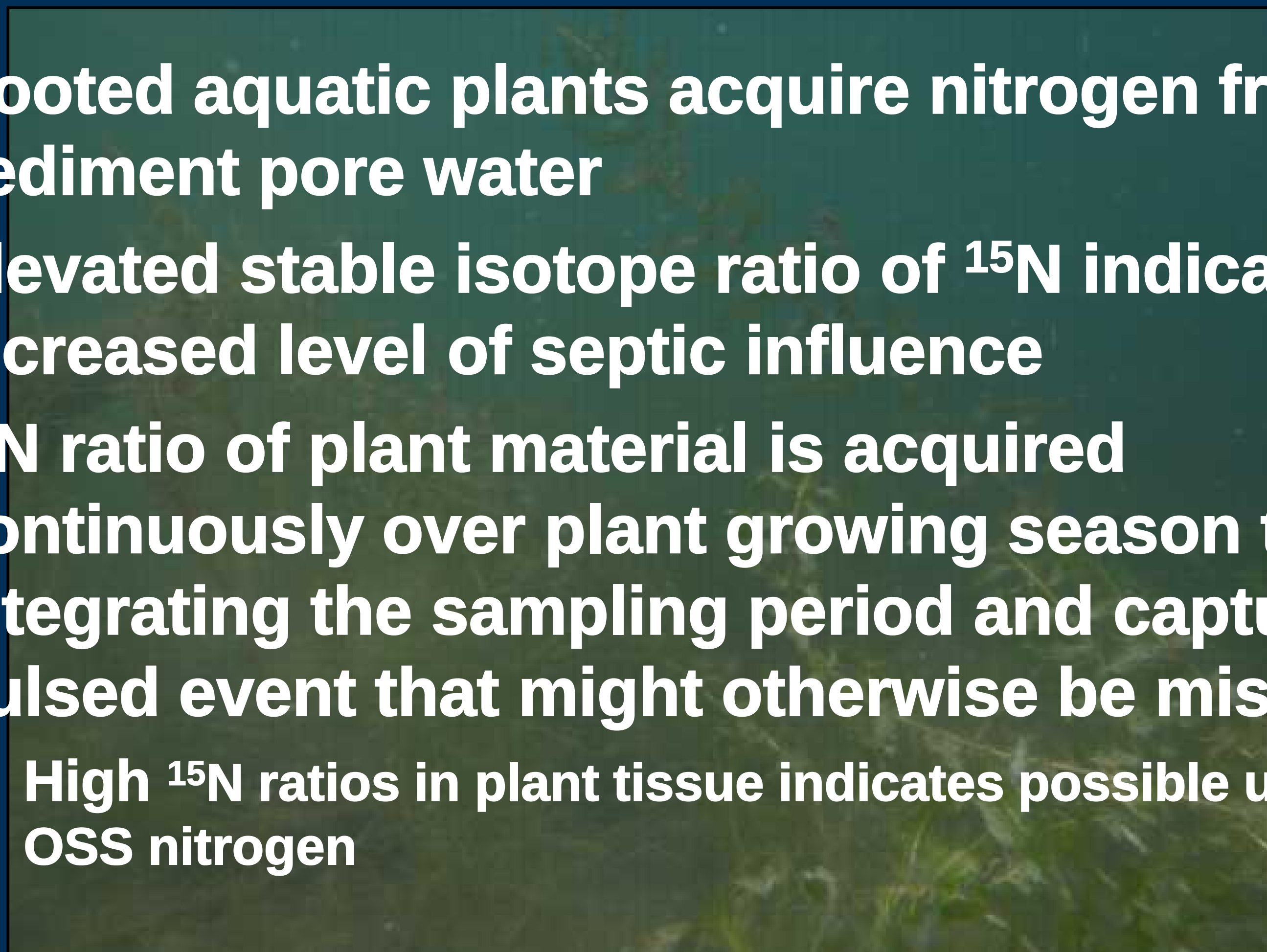
Why sample plants for ^{15}N?



- Rooted aquatic plants acquire nitrogen from bed-sediment pore water
- Elevated stable isotope ratio of ^{15}N indicative of increased level of septic influence
- ^{15}N ratio of plant material is acquired continuously over plant growing season thus integrating the sampling period and capturing pulsed event that might otherwise be missed
  - High ^{15}N ratios in plant tissue indicates possible uptake of OSS nitrogen

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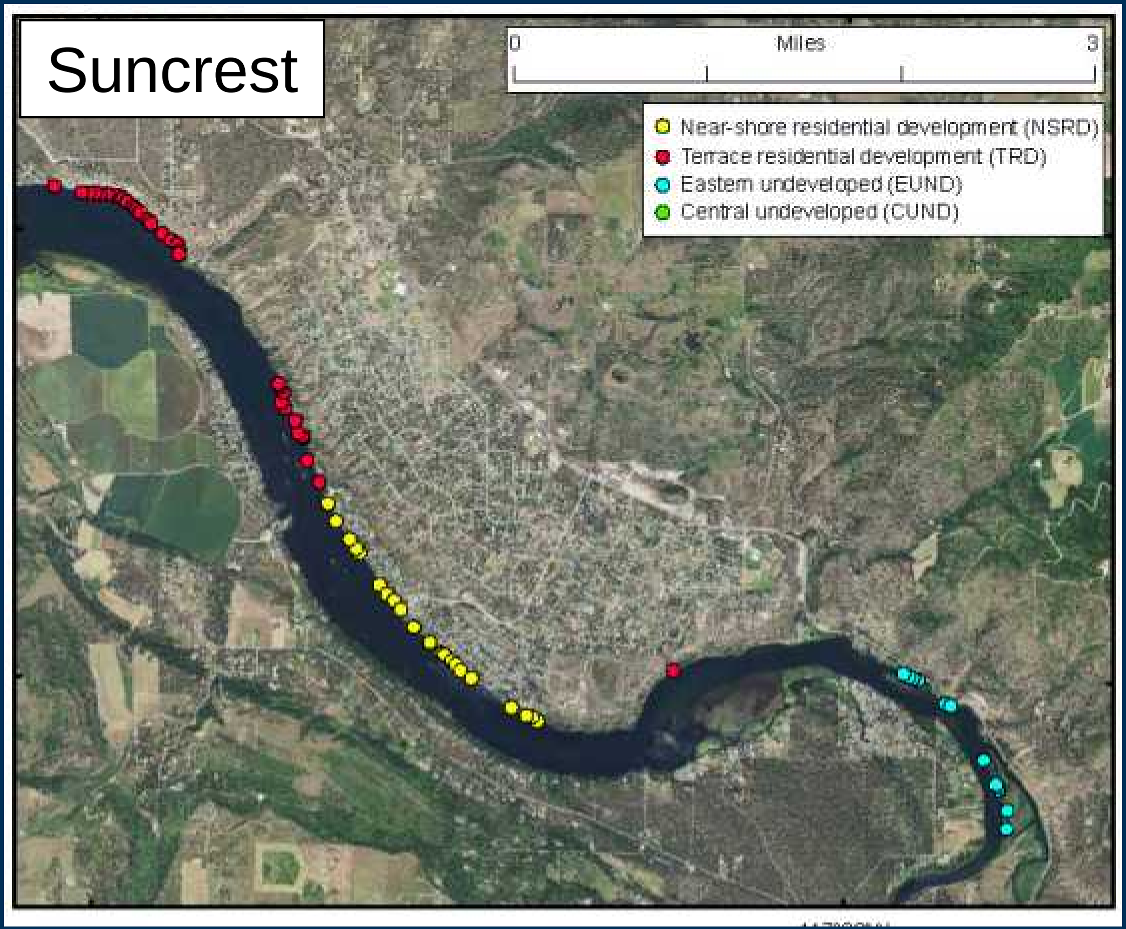
Locations of aquatic vegetation samples analyzed for δ^{15}N



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Sampling of aquatic vegetation & analysis

- Sample rooted aquatic vegetation (Richardson's pond weed) in Lake Spokane (Aug/Sept 2014)
- Dried, processed, and weighed at USGS office in Tacoma
- Analyzed for ^{15}N at UC Davis stable isotope lab

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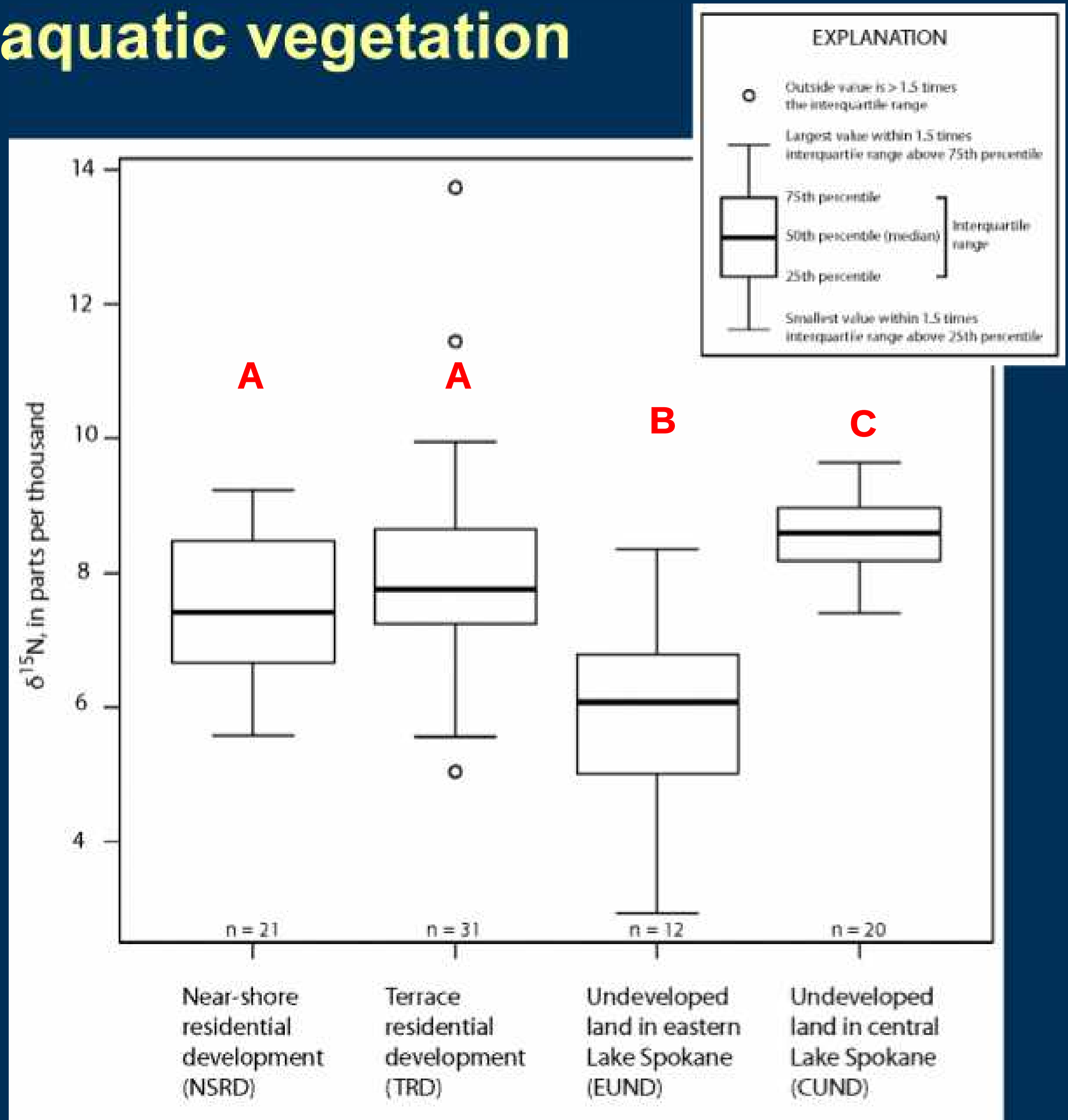
Results: δ[15]N in aquatic vegetation

- **δ[15]N in EUND area was significantly less than other land use groups**
- **δ[15]N in CUND area was significantly greater than other land use groups**



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Sampling of Shallow Groundwater

- Sampled filtered GW in March and April, 2015 for dissolved nutrients (nitrate+nitrite, ammonia and orthophosphate)
- Samples collected from 30 locations across same land use areas (not CUND)
- Samples chilled and shipped to USGS water quality lab for analysis
- At 21 of 30 sites, also measured vertical hydraulic gradients to identify groundwater discharge

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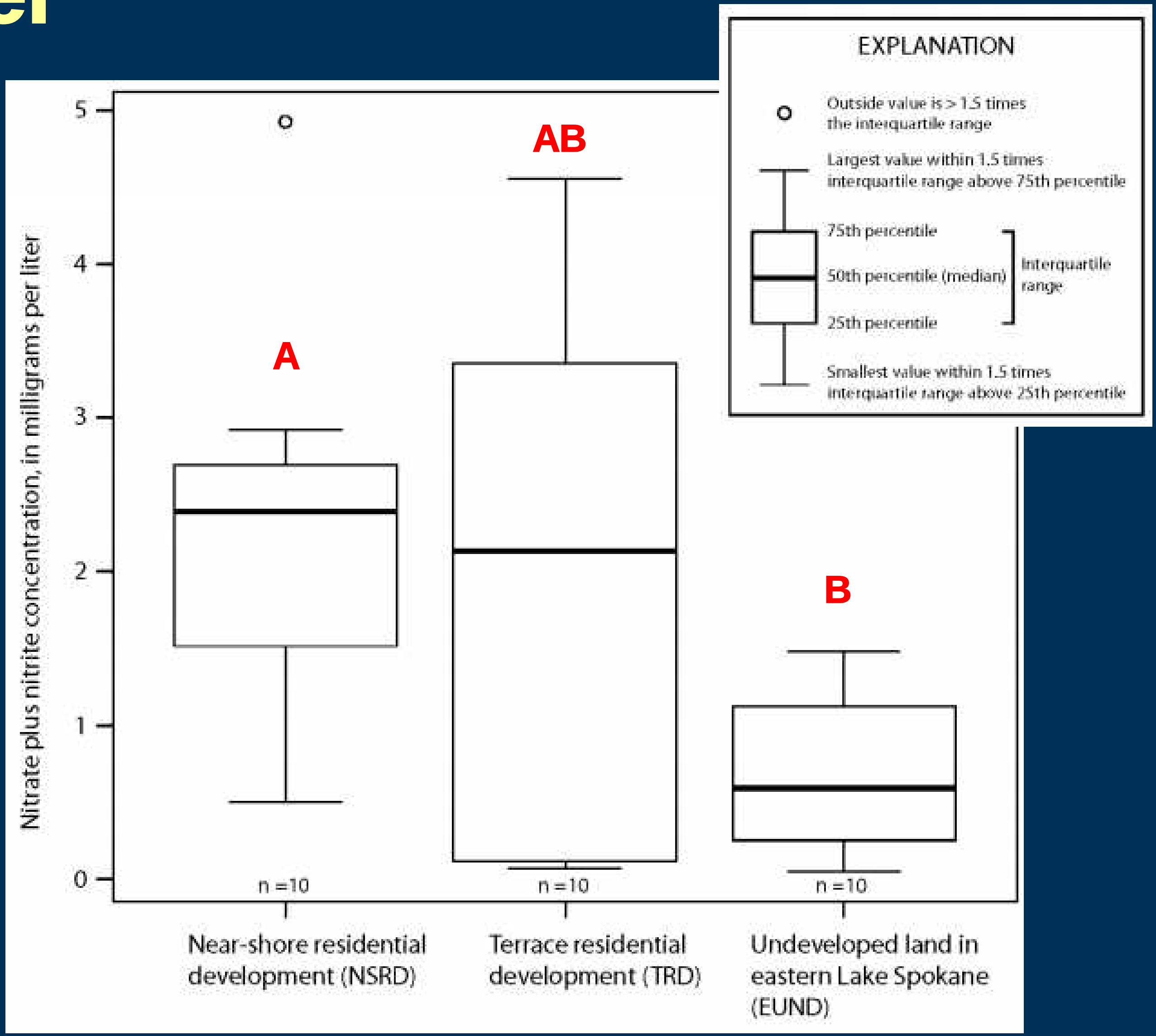
Results: Nitrate plus nitrite in groundwater

- EUND < NSRD (p-value <0.001)
- Other populations were not statistically different from each other



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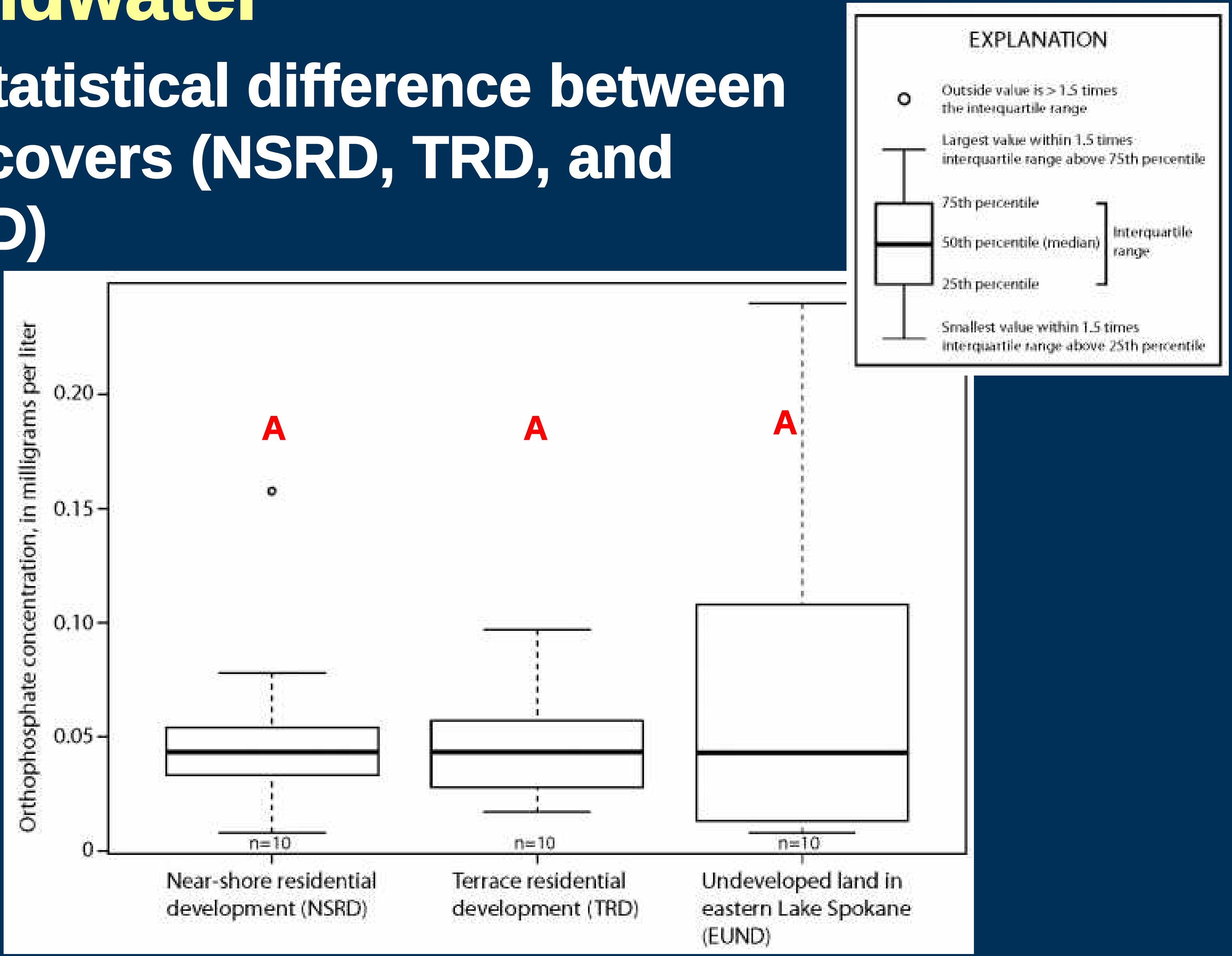
Results: Orthophosphate in groundwater

- **No statistical difference between landcovers (NSRD, TRD, and EUND)**



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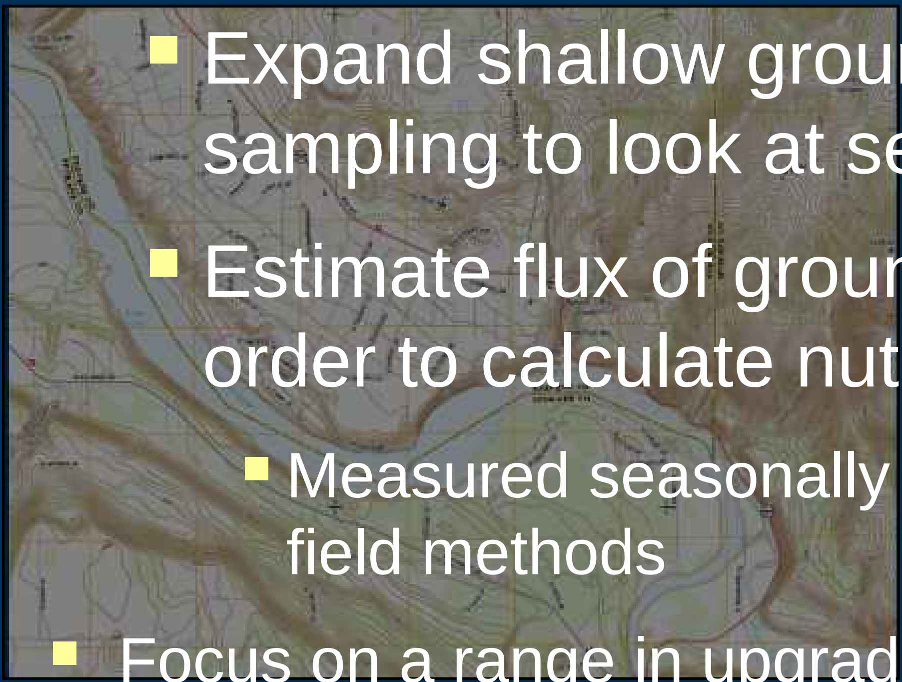
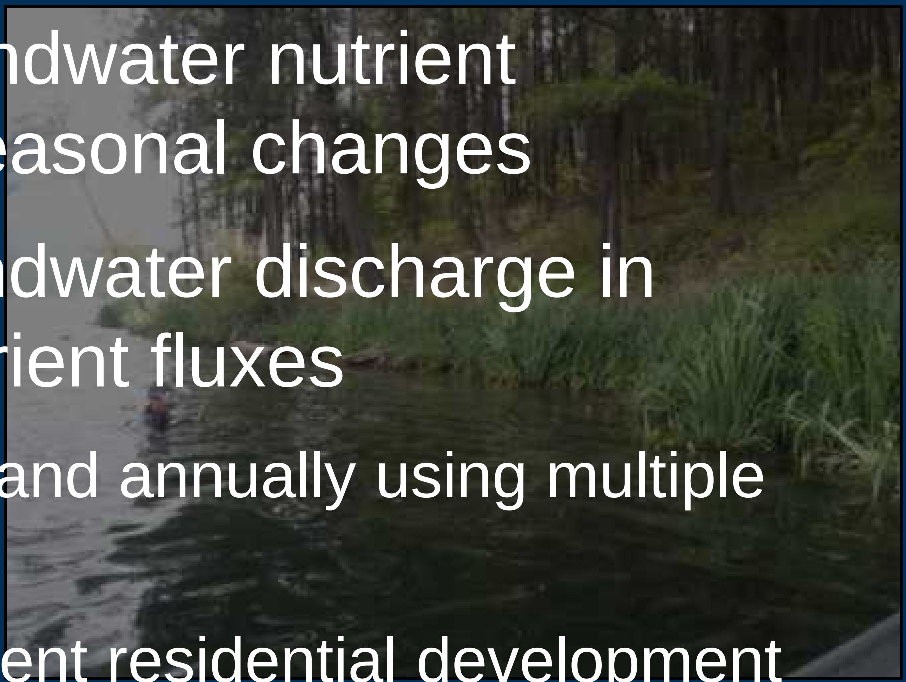
Phase 2 Approach

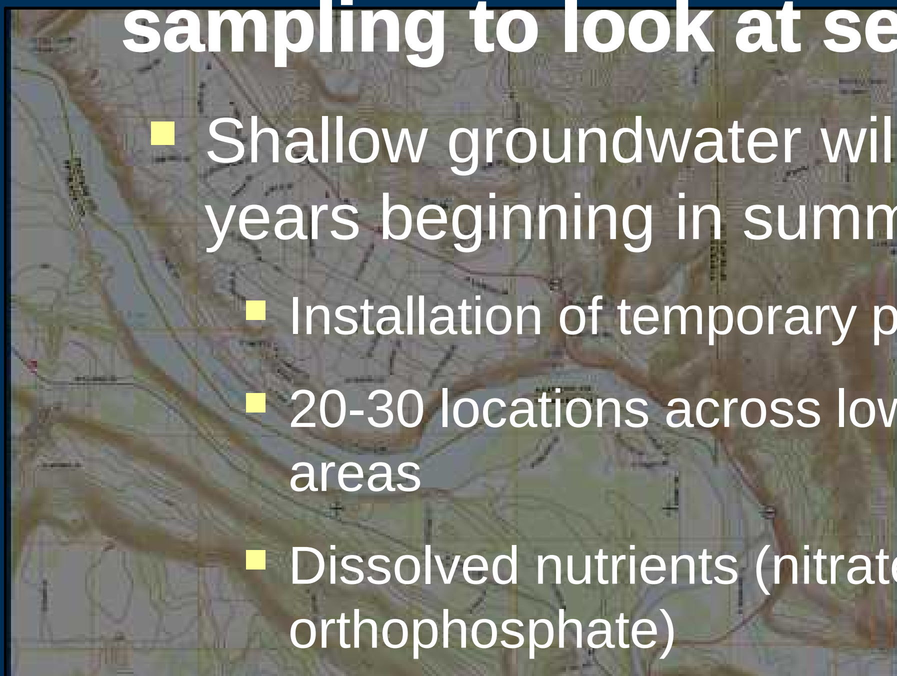
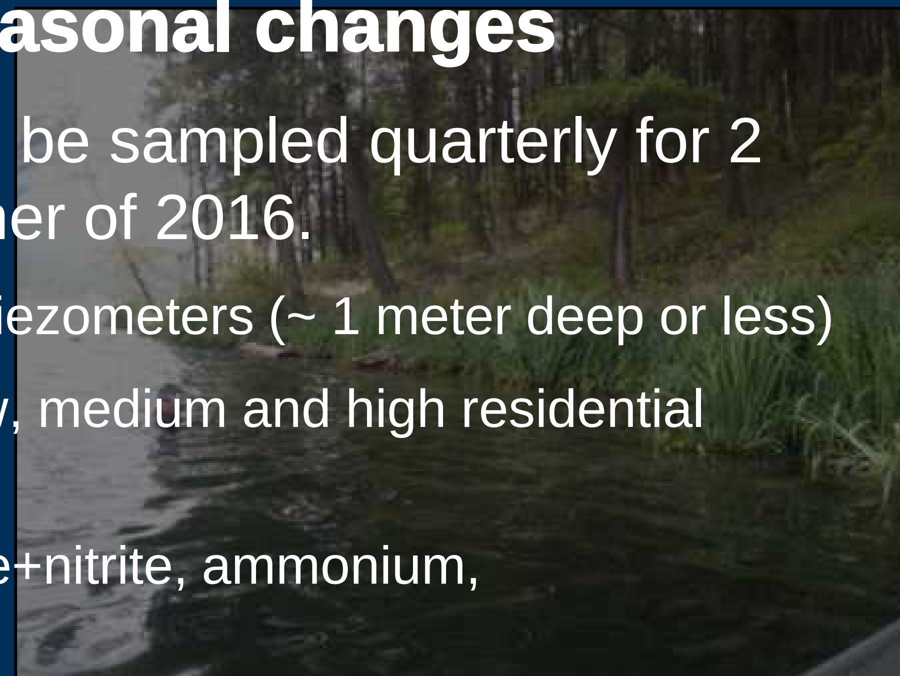
- **Build on phase 1 information in two ways**





  - Expand shallow groundwater nutrient sampling to look at seasonal changes
  - Estimate flux of groundwater discharge in order to calculate nutrient fluxes
    - Measured seasonally and annually using multiple field methods
- Focus on a range in upgradient residential development similar to phase 1

Phase 2 Approach

- **Expand shallow groundwater nutrient sampling to look at seasonal changes**
  - Shallow groundwater will be sampled quarterly for 2 years beginning in summer of 2016.
    - Installation of temporary piezometers (~ 1 meter deep or less)
    - 20-30 locations across low, medium and high residential areas
    - Dissolved nutrients (nitrate+nitrite, ammonium, orthophosphate)

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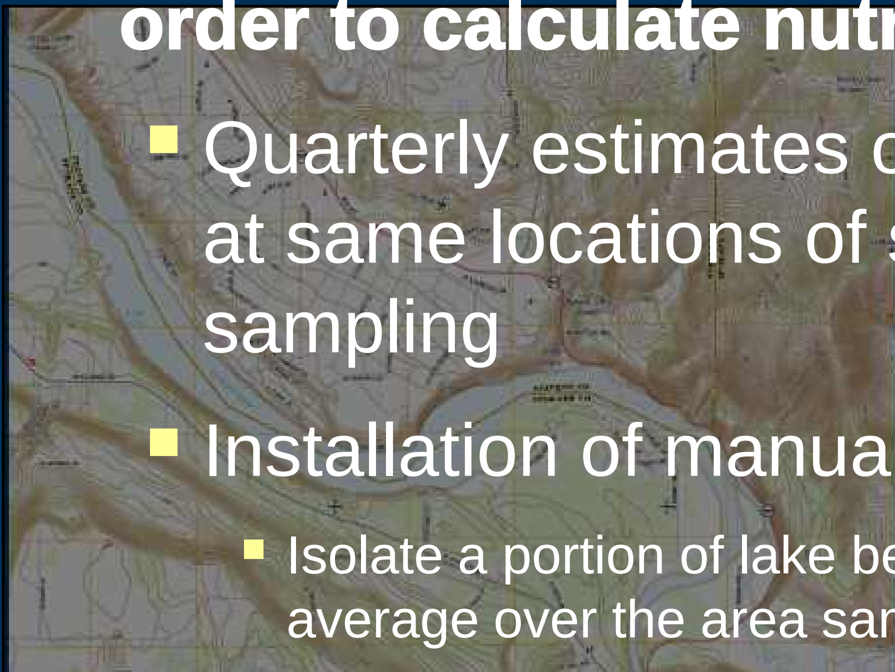
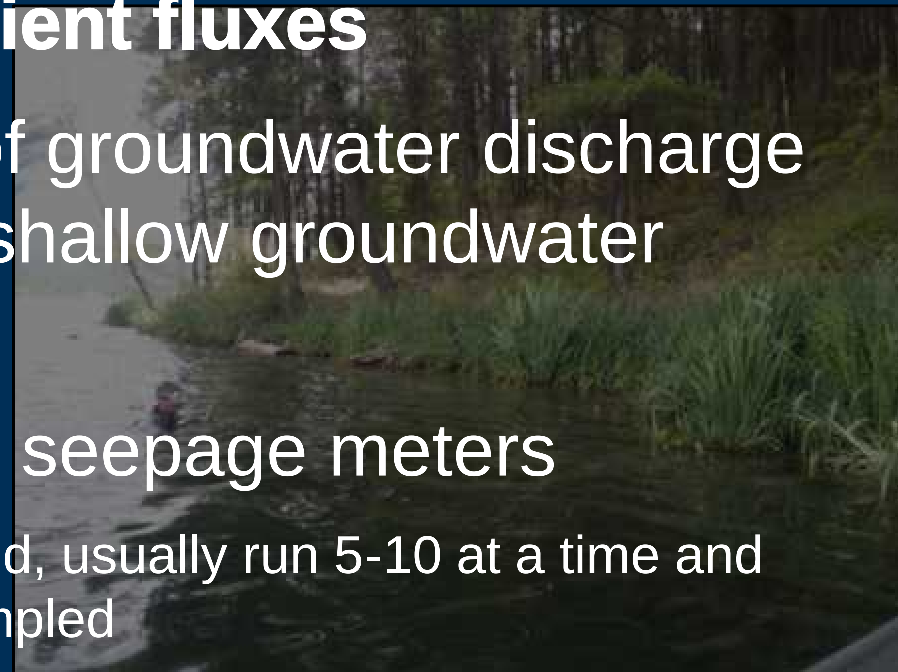
Phase 2 Approach

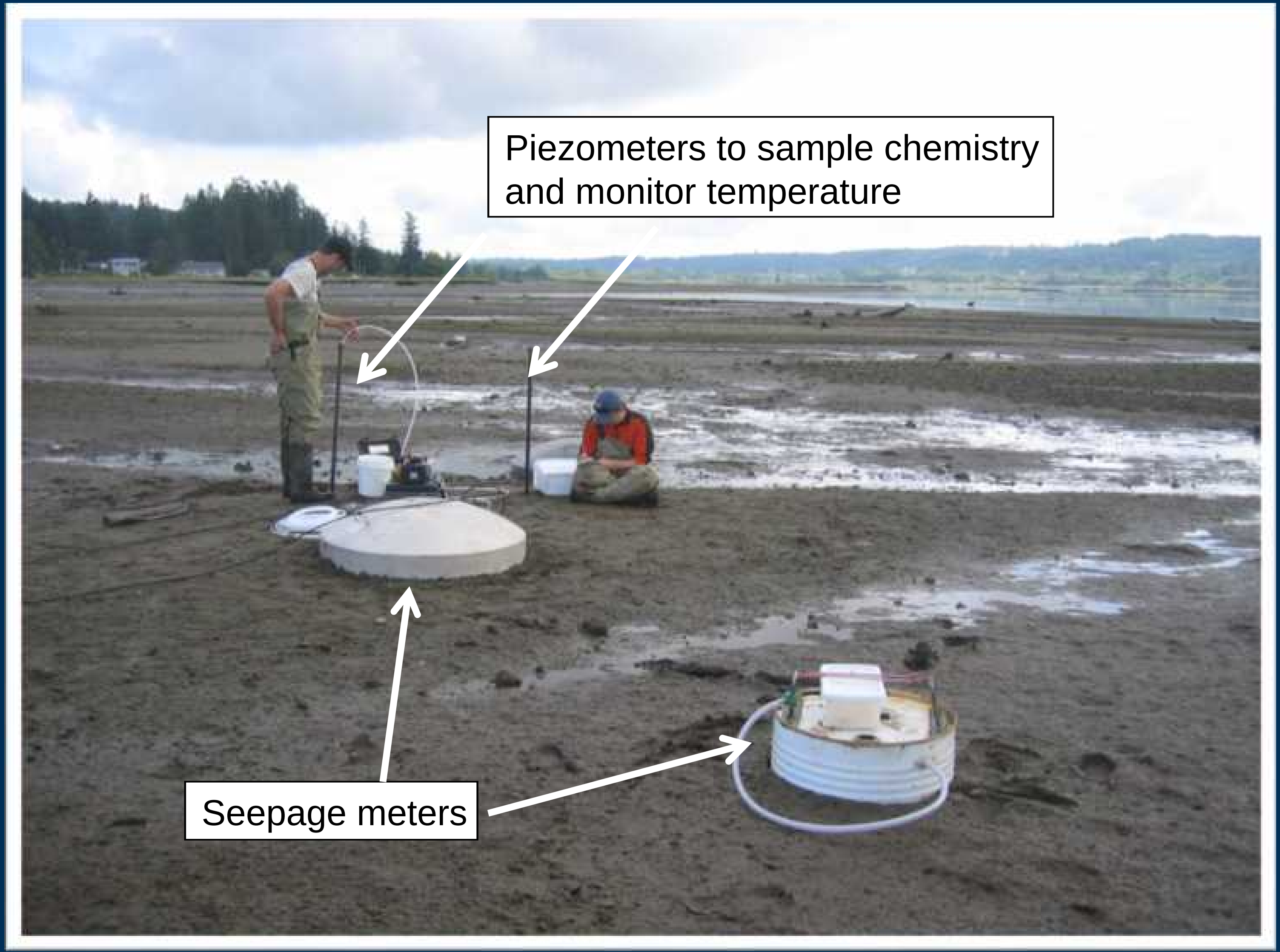
- **Estimate flux of groundwater discharge in order to calculate nutrient fluxes**



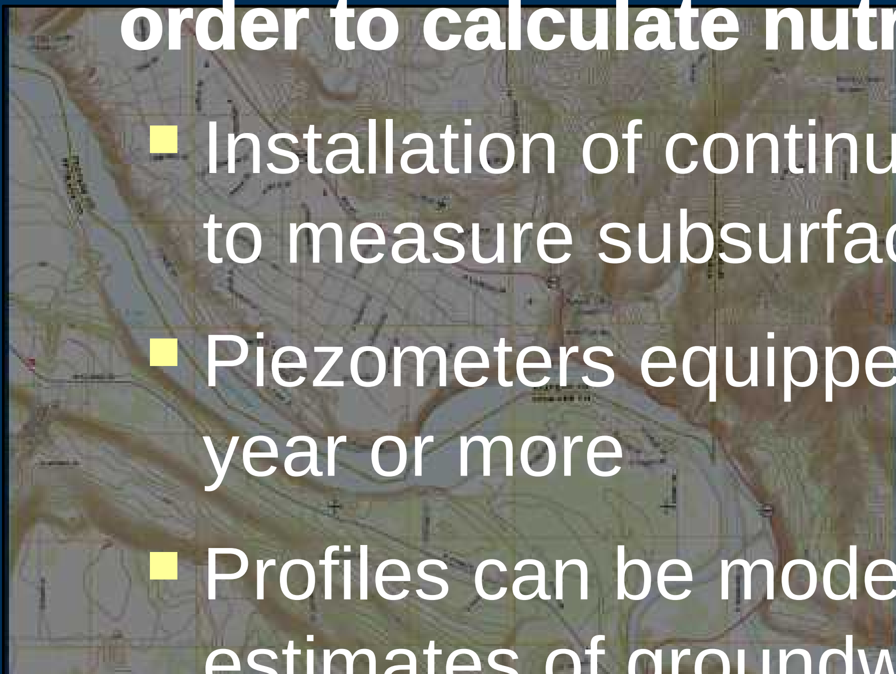


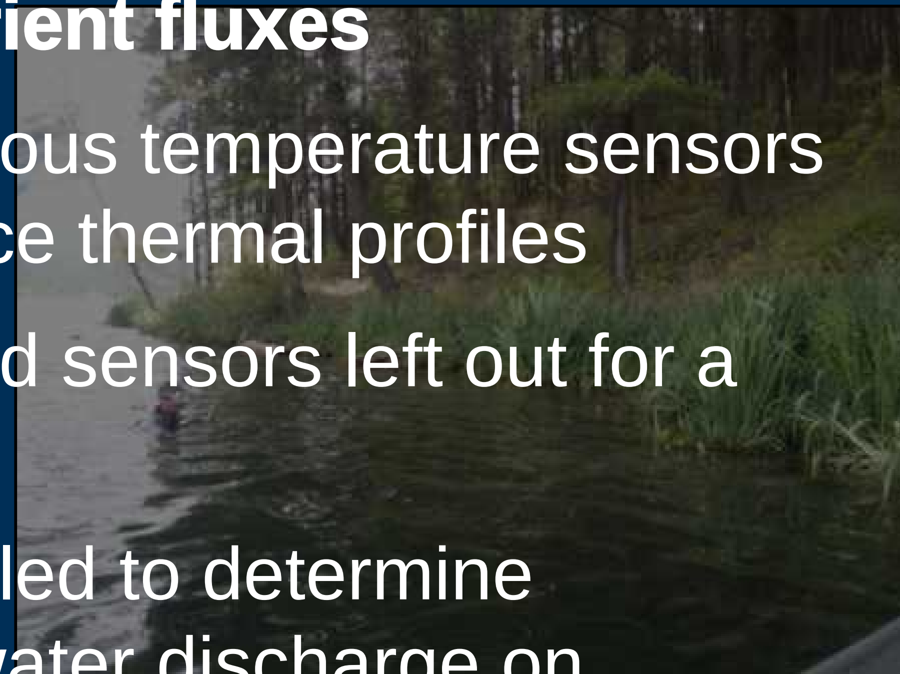
  - Quarterly estimates of groundwater discharge at same locations of shallow groundwater sampling
  - Installation of manual seepage meters
    - Isolate a portion of lake bed, usually run 5-10 at a time and average over the area sampled
    - Determine change in volume of water in a flexible capture bag
    - Estimate of discharge at one point in space and time

Seepage meter measurements



Phase 2 Approach





- **Estimate flux of groundwater discharge in order to calculate nutrient fluxes**
  - Installation of continuous temperature sensors to measure subsurface thermal profiles
  - Piezometers equipped sensors left out for a year or more
  - Profiles can be modeled to determine estimates of groundwater discharge on varying time scales.

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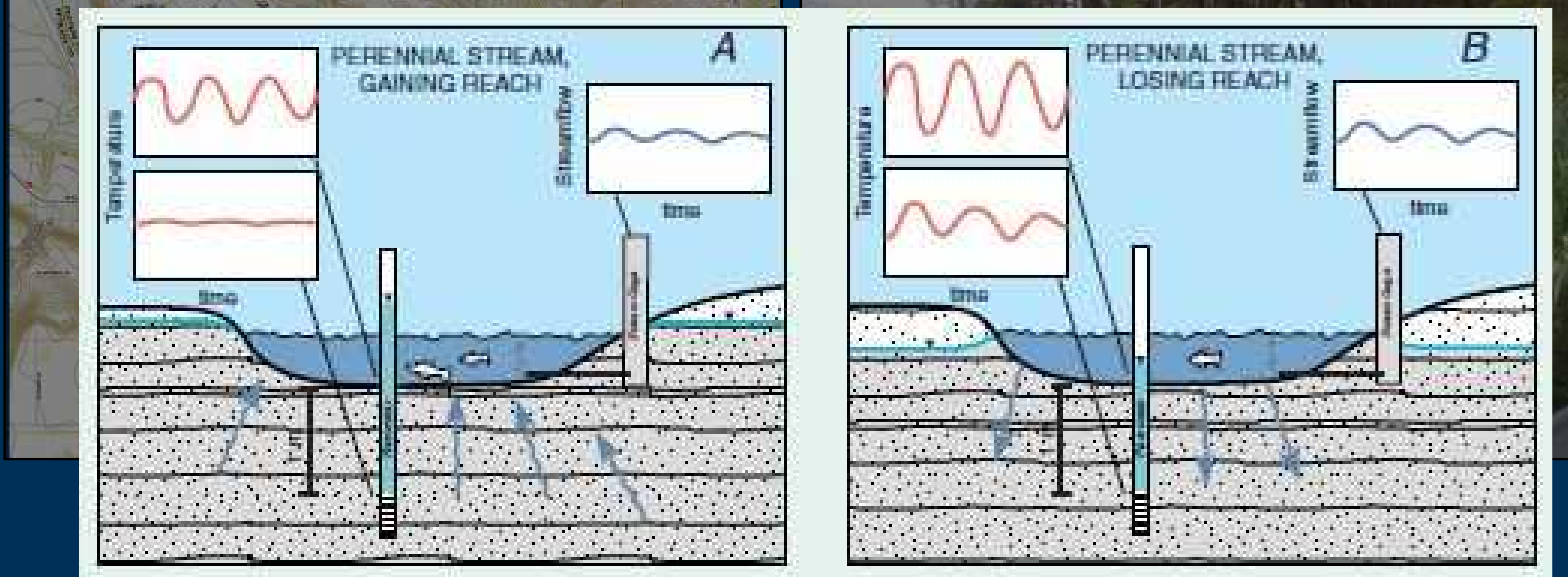
Phase 2 Approach

- **Temperature modeling to estimate groundwater flux from heat balance equations**



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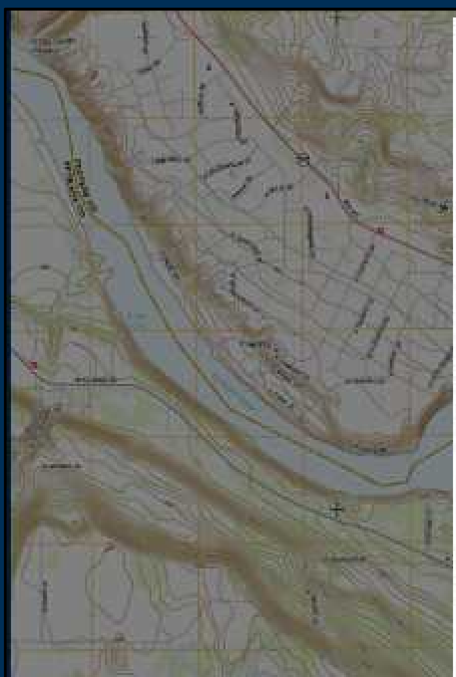
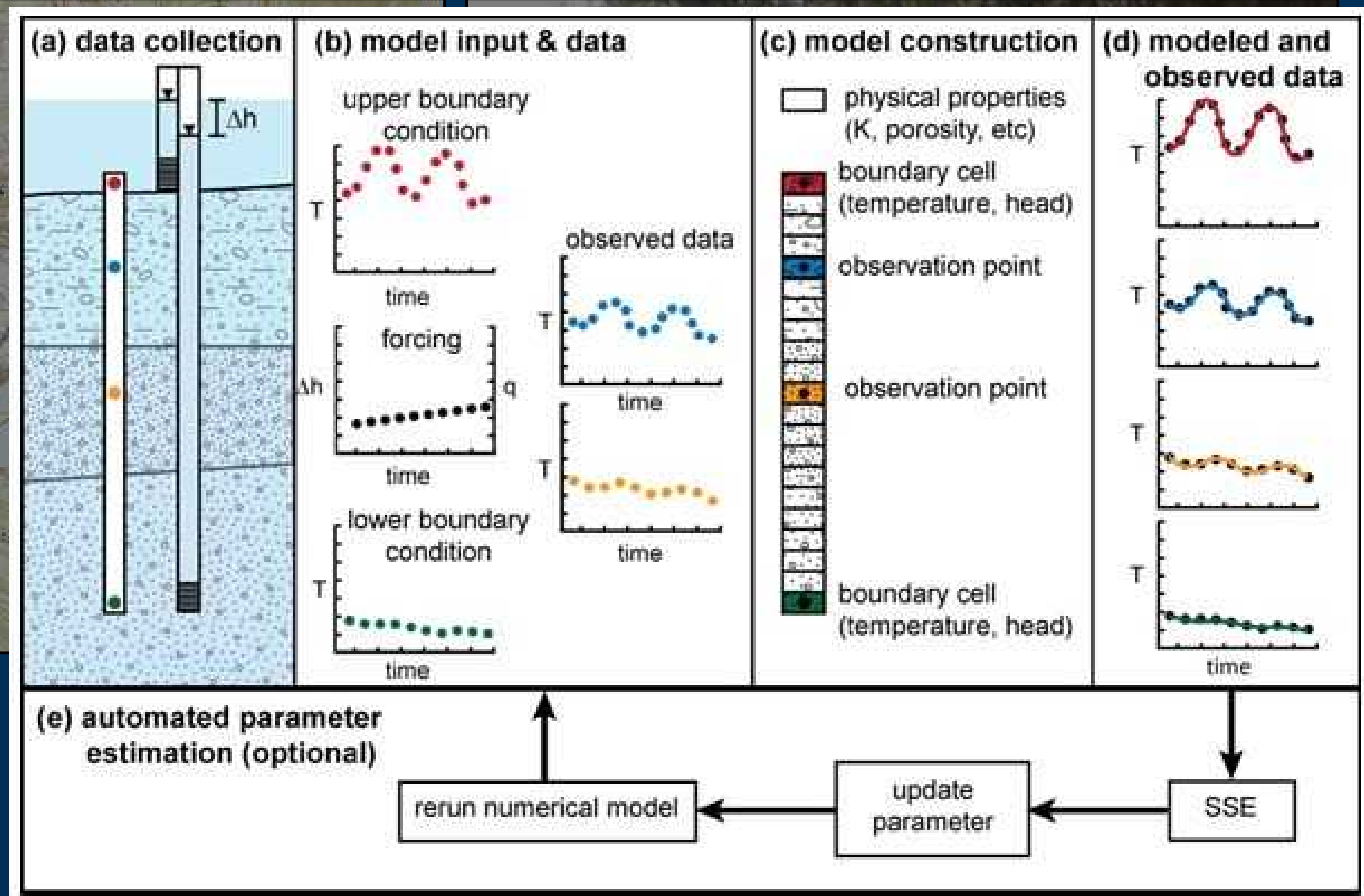
Phase 2 Approach

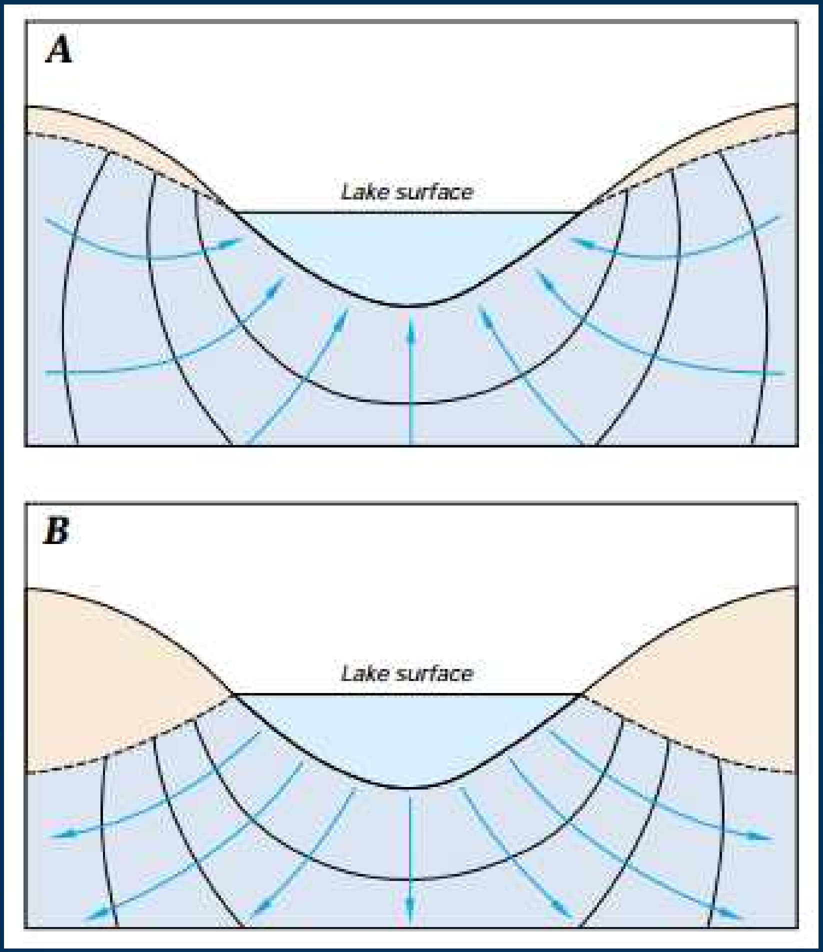
- **USGS model (1DTempPro)**





Groundwater Flow Pathways and GW/SW Interactions

- GW may discharge to or from a lake depending on its hydraulic relation to the lake
- GW/SW interactions may vary seasonally with changes in lake stage



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Summary

- Lower $\delta^{15}N$ at EUND supported selection of EUND as undeveloped landcover for subsequent GW sampling
- Nitrogen: GW samples downgradient from both developed land covers (NSRD and TRD) were elevated relative to EUND
- Phosphorus: GW samples at EUND were not statistically different compared to samples downgradient from the two developed landcovers (NSRD and TRD)
- Nitrogen is more mobile in GW compared to phosphorus, which sorbs to sediments
- Seasonal variation in nutrient concentrations and fluxes of nutrients from GW remain unquantified

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Publication and Project Website

- Gendaszek, A.S., Cox, S.E., and Spanjer, A.R., 2016, Preliminary characterization of nitrogen and phosphorus in groundwater discharging to Lake Spokane, northeastern Washington, using stable nitrogen isotopes: U.S. Geological Survey Open-File Report 2016-1029, 22 p., http://dx.doi.org/10.3133/ofr20161029

- **http://wa.water.usgs.gov/projects/lakespokane/**